Project no.:
**229196**

Project acronym:
# piezoVolume

Project full title:
*High volume piezoelectric thin film production process for microsystems*

**Collaborative Project targeted to a special group (such as SMEs)**
**Grant Agreement No.:**

**NMP2-SE-2009-229196**

Start date of project: 2010-01-01
Duration: 3 years

# D 2.13
# Final wafer level in-line quality monitoring tool

Due delivery date: 2012-08-31
**Actual delivery date: 2012-09-04**

Organisation name of lead contractor for this deliverable: aixACCT

| Project co-funded by the European Commission within the Seventh Framework Programme (2008-2011) | | |
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| **Dissemination Level** | | |
| **PU** | Public | |
| **PP** | Restricted to other programme participants (including the Commission Services) | |
| **RE** | Restricted to a group specified by the consortium (including the Commission Services) | |
| **CO** | Confidential , only for members of the consortium (including the Commission Services) | X |

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| **Deliverable number:** | D 2.13 |
| **Deliverable name:** | Final wafer level in-line quality monitoring tool-AIX |
| **Work package:** | WP2 |
| **Lead contractor:** | AIX |



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## Abstract

Piezoelectric MEMS are becoming a mass market in the very near future. Testing and characterization plays a decisive role for process optimization and quality control during the process development and the production cycle. The system designed within this deliverable is capable of deriving material as well as device properties and therefore is an essential tool for the piezoMEMS industry. It helps to distinguish between material and device failures, it ensure material quality (standard properties like displacement, piezoeelctric coefficient, but also reliability data) at an early stage of production cycle before costly processing steps start. In the same tool devices can be tested and therefore makes it a valuable tool for MEMS industry

AIX has realized a high throughput in-line quality monitoring tool for wafer level characterization of piezoelectric thin film performance during fabrication.


## Public introduction[1]

aixACCT Systems has developed a high throughput in-line quality monitoring tool for electrical, electro-mechanical and partly mechanical wafer level characterization of piezoelectric thin film performance during fabrication.

Film properties as well as device performance can be comprehensively tested in one and the same tool.

[1] According to Deliverables list in Annex I, all restricted (RE) deliverables will contain an introduction that will be made public through the project WEBsite

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# 1 TOOL DEVELOPMENT

One fo the major goals of the project has been to develop a tool for quality control of piezoelectric thin films. The tool is based on an auto-probe positioning system for 150 mm and 200 mm wafers. AIX had adapted its core technology of optical double beam laser interferometry and the know-how on electrical and piezoelectric test systems to a Cascade Microtech auto prober system. Therefore, the aixDBLI based on a commercial auto prober offers right away a high MTBF (mean time between failure) and guarantees a short MTTR (mean time to repair). These are crucial demands from industry for their production equipment.

Additional reasons for the auto probe system are as follows:

- high resolution in x-y- positioning (better +/- 2µm)
- excellent z-resolution +/- 1µm to avoid scratches on the wafer surface by contact probes
- auto prober is already designed to operate e.g. with Genmark wafer handler and the whole integrated aixDBLI system offers a SECS/GEM interface for In Line use too

## 1.1 Hardware development

The assembled hardware consists of a vibration isolation chamber including the wafer prober and the Double Beam Laser Interferometer optical core parts and optional space for the later integration of an automatic wafer handler (Genmark). Additional components like wafer view cameras e.g. for a pattern recognition system, contact probes and an in-chamber monitor are included too. Figure 1.1.1 shows the optical beam path and components of the Double Beam Laser Interferometer. The overall assembly of the components is displayed in the schematic in Figure 1.1.2. The hardware components included in the rack mount are shown in detail then in Figure 1.1.3. The two monitors are touch screens which allow in conjunction with the developed measurement software an easy use of the system even in a clean room environment. The dimensions and heights e.g. of monitors and keyboard are compliant with the relevant Semi standards S2 and S8 from semiconductor industry. Figure 1.1.4 and Figure 1.1.5 show the finally assembled system which is ready to do automated measurements on the expected samples from the project.

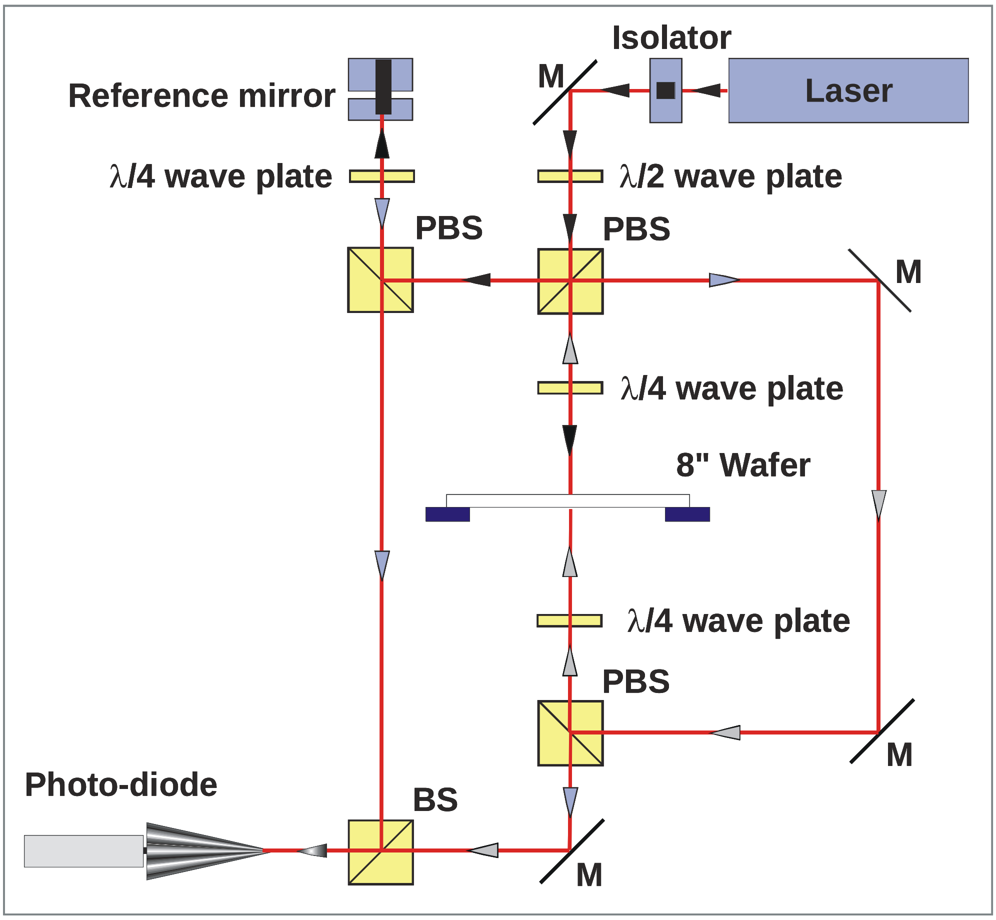



Figure 1.1.1: Double Beam Laser Interferometer optical path

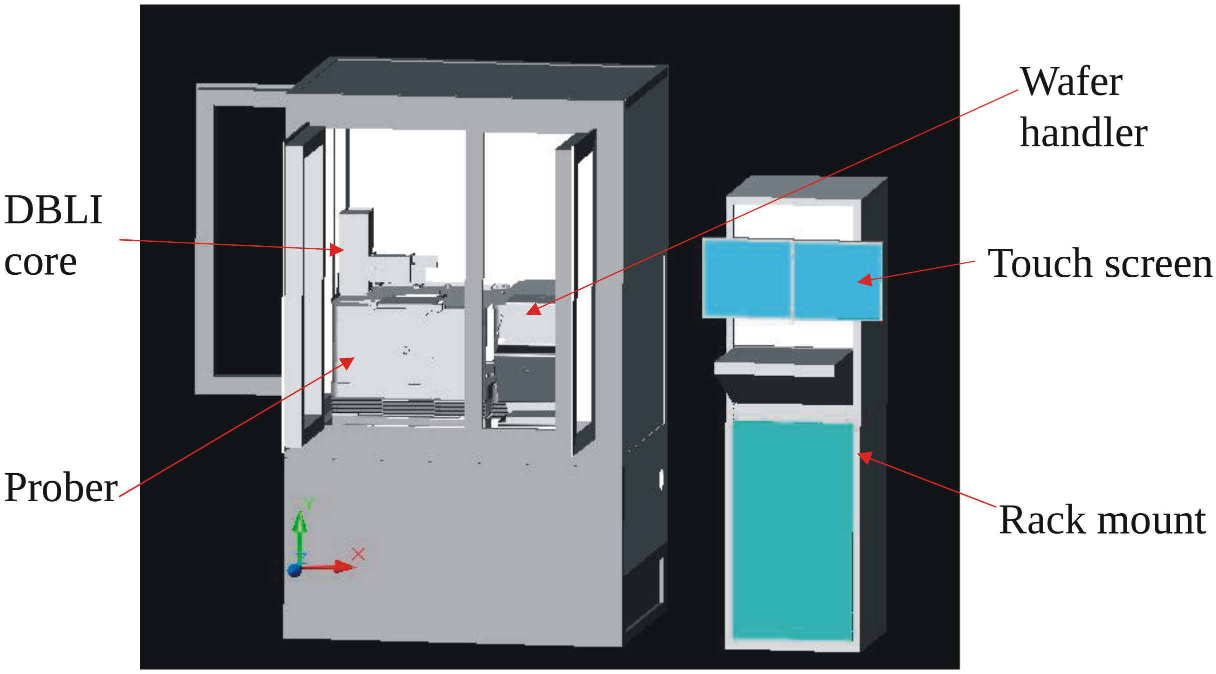



Figure 1.1.2: Schematic of the aixDBLI components

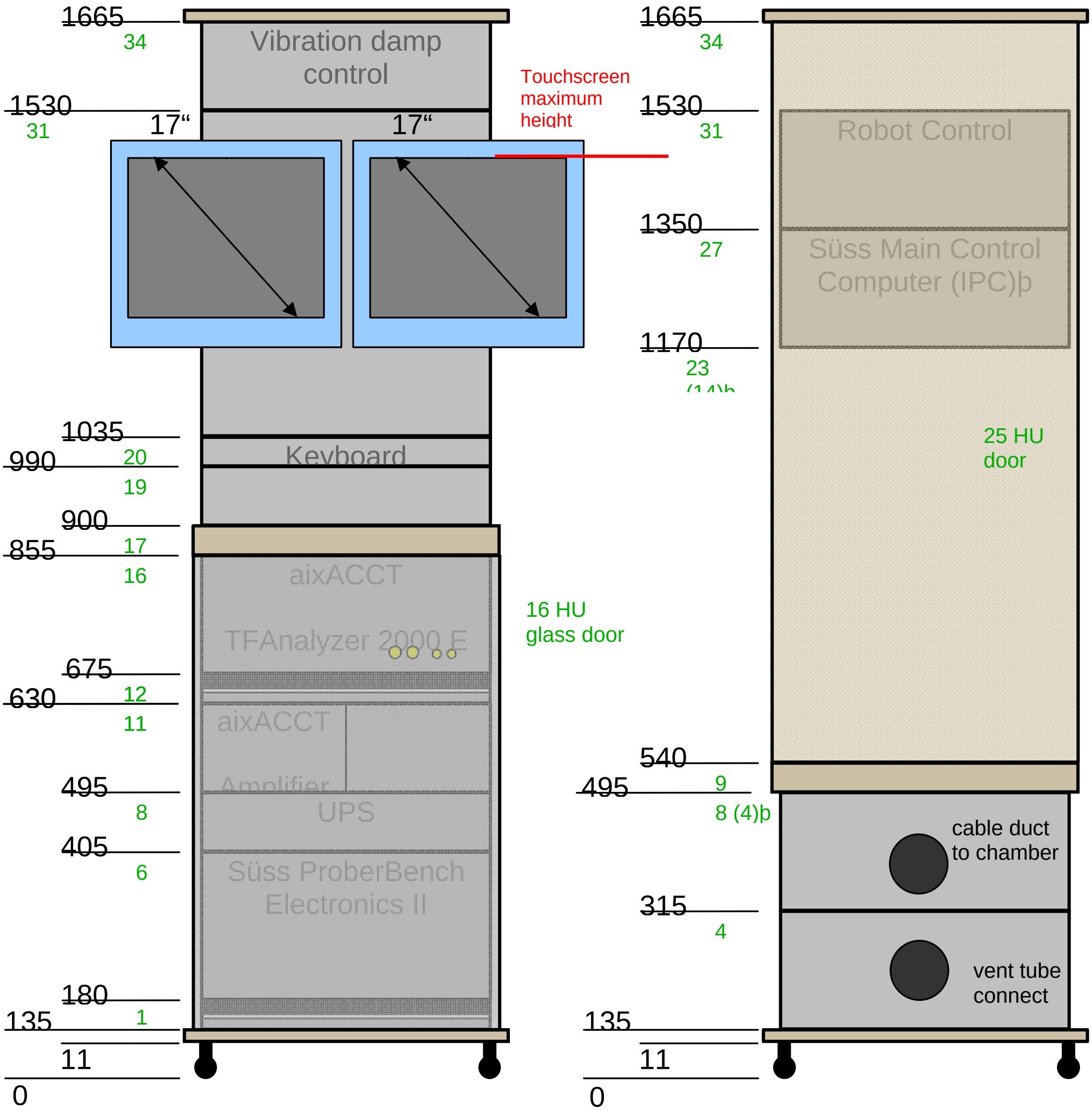



Figure 1.1.3: Components and dimensions of the rack mount (compliant with Semi standards S2 and S8)


Figure 1.1.4: Picture of the assembled aixDBLI system

Figure 1.1.5: Inside view of the aixDBLI chamber without additional functionality of device testing and force measurement

## 1.2 Software development

AIX has decided for touch screen operated software for controlling and operating the in-line quality monitoring tool due to demands in clean room applications. In order to be operated in a production environment a SECS/GEM interface is required and has been established. This interface allows asking for status information of the aixDBLI tool at any time throughout the lifetime. For this reason each component of the aixDBLI tool generates status information, which are indicated by a “traffic light”. The requested system status information is displayed in Figure 1.1.6.

The software ensures communication between the piezoelectric measurement electronics and the auto probe system to generate wafer map information, which allows checking the homogeneity of the deposition process and therefore gives feedback for process optimization.

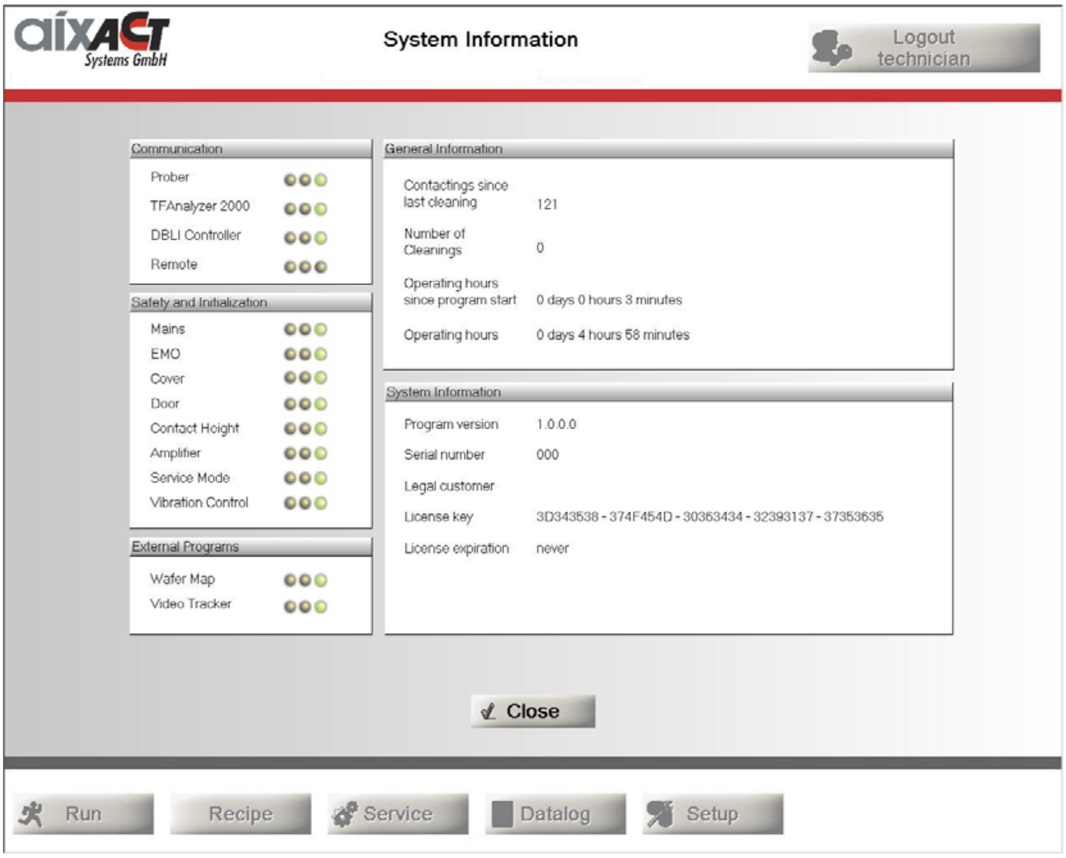



Figure 1.1.6: Status information of the system

Typically the right monitor shows the buttons and menus to operate the system (see Figure 1.1.7) whereas the left monitor displays the pictures e. g. of the wafer camera (see Figure 1.1.8) or the wafer map view of a running measurement. Fully automated measurements are possible when the system is additionally equipped with wafer handler and pattern recognition system. This allows then to automatically load a specified wafer from a wafer cassette onto the auto prober, orient and align the wafer by approaching two pre-defined alignment marks. Afterwards, the whole wafer can be measured according to a selected recipe. This recipe consists of the dies and positions within to be measured, the type of measurement(s) with specified parameters and additional necessary information. Two typical measurements for piezoelectric thin films are the large signal polarization and displacement (see Figure 1.1.9) and the small signal dielectric and piezoelectric coefficient measurement (see Figure 1.1.10). These are the measurements of a single spot. The result of a wafer map distribution e. g. of the effective longitudinal piezoelectric coefficient d33,f is shown in Figure 1.1.11. For further evaluation of measurement results a special software tool named aixPert has been developed.

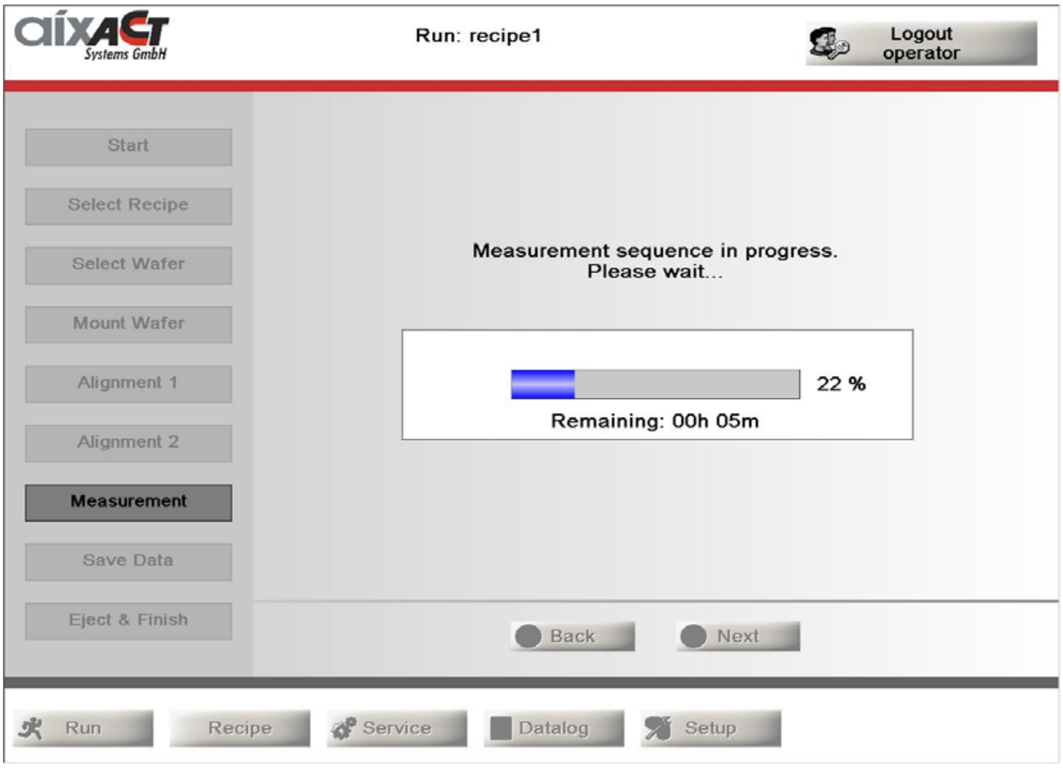


Figure 1.1.7: Graphical user interface of the measurement software operated by touch screen

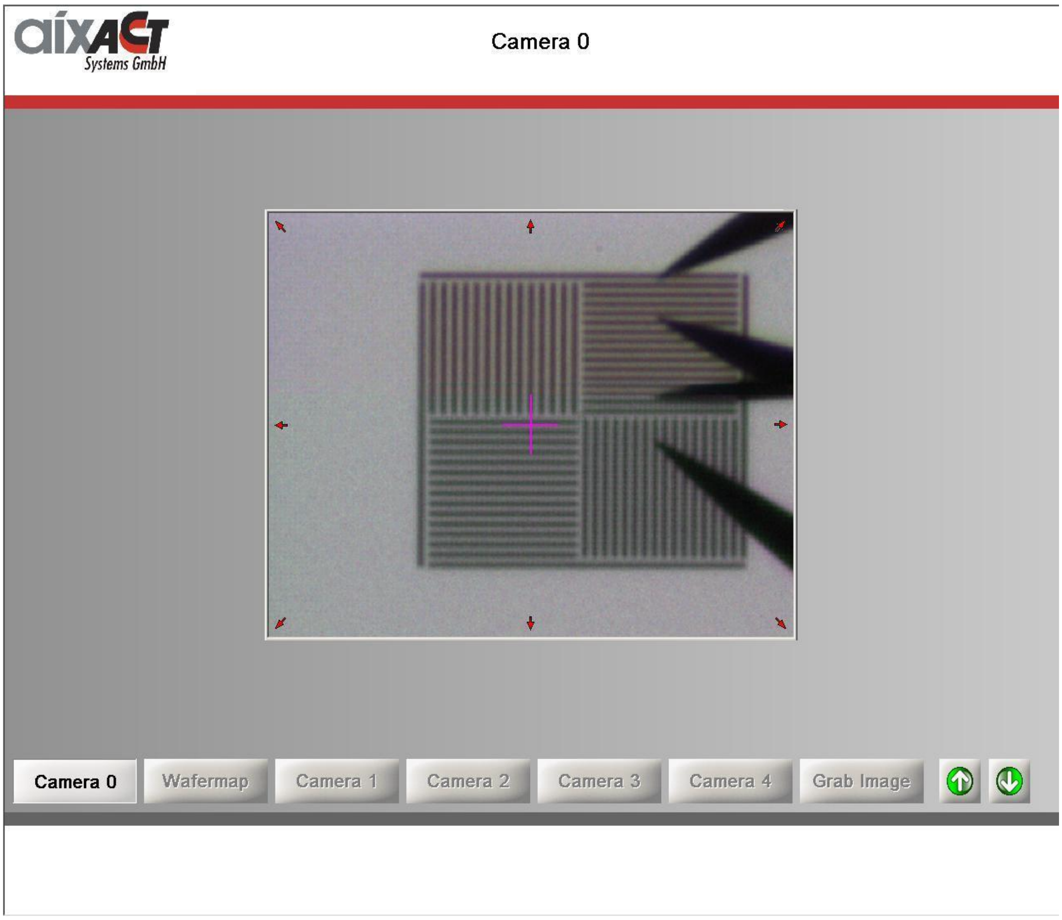



Figure 1.1.8: Wafer view camera picture of a alignment structure

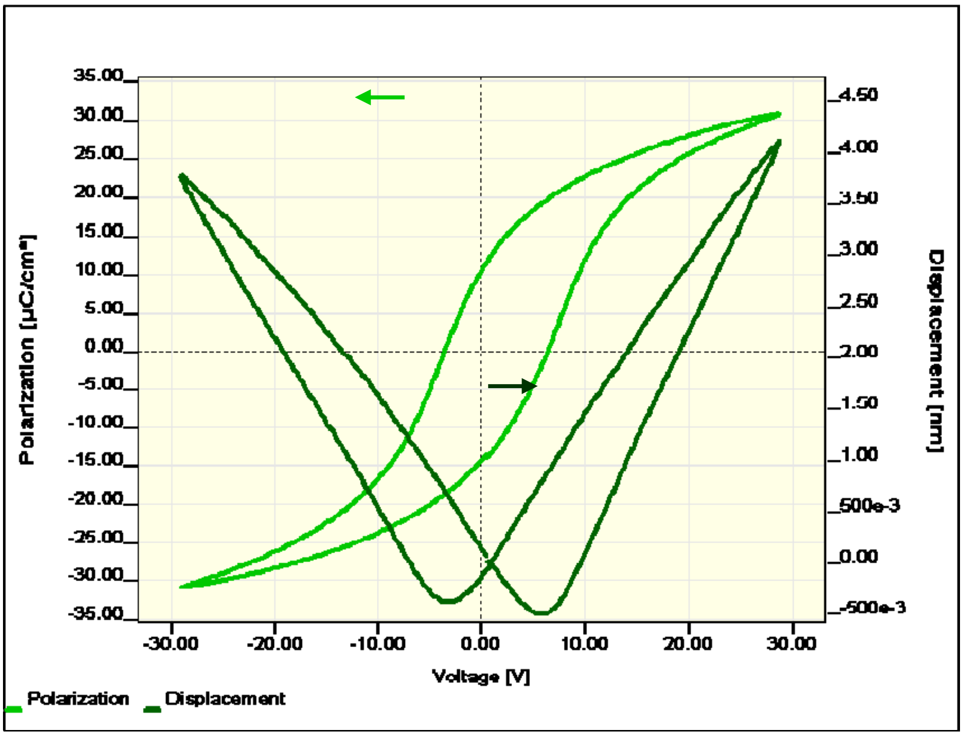



Figure 1.1.9: Test measurements of large signal polarization and displacement response vs. applied excitation voltage of a PZT thin film sample

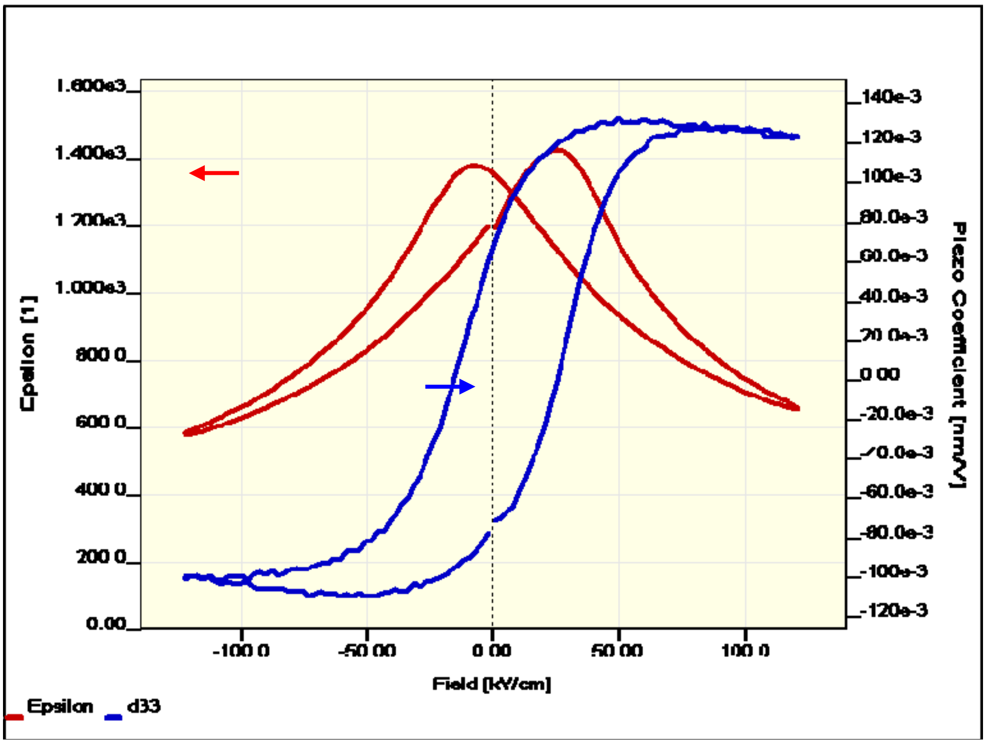



Figure 1.1.10: Test measurement of small signal dielectric and piezoelectric response vs. applied DC bias voltage of a PZT thin film sample

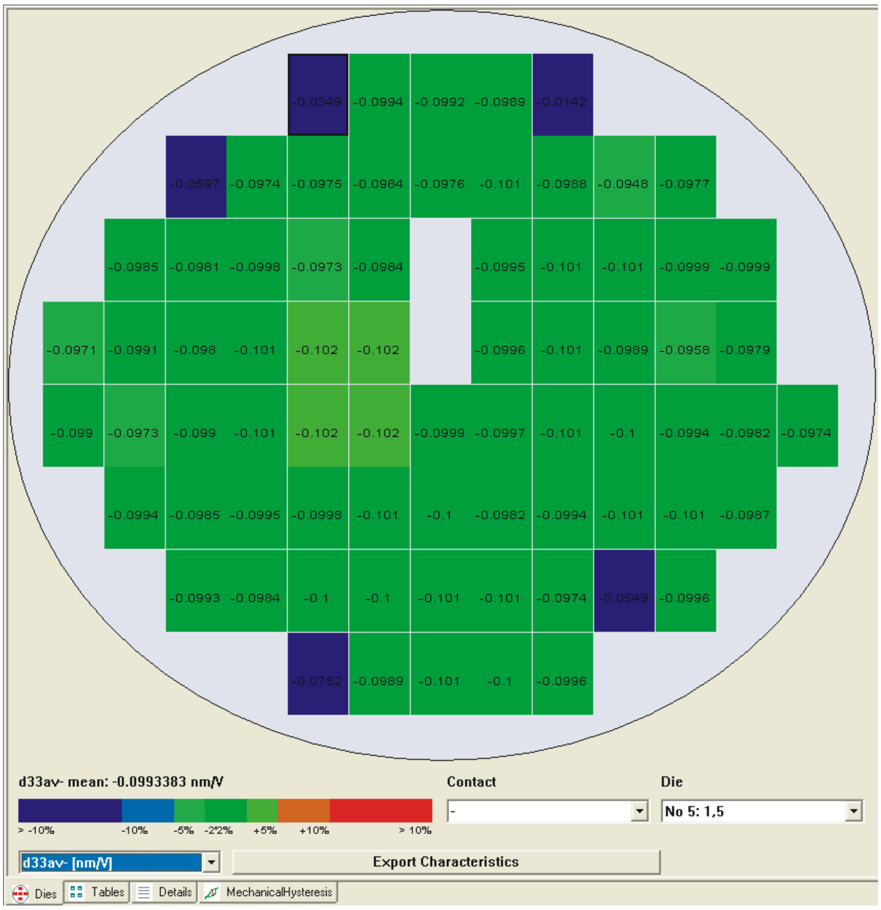



Figure 1.1.11: Wafer map view in the aixPlorer software tool for statistical data evaluation

# 2 SOFTWARE MODIFICATIONS FOR HIGH VOLUME PRODUCTION QUALITY MONITORING

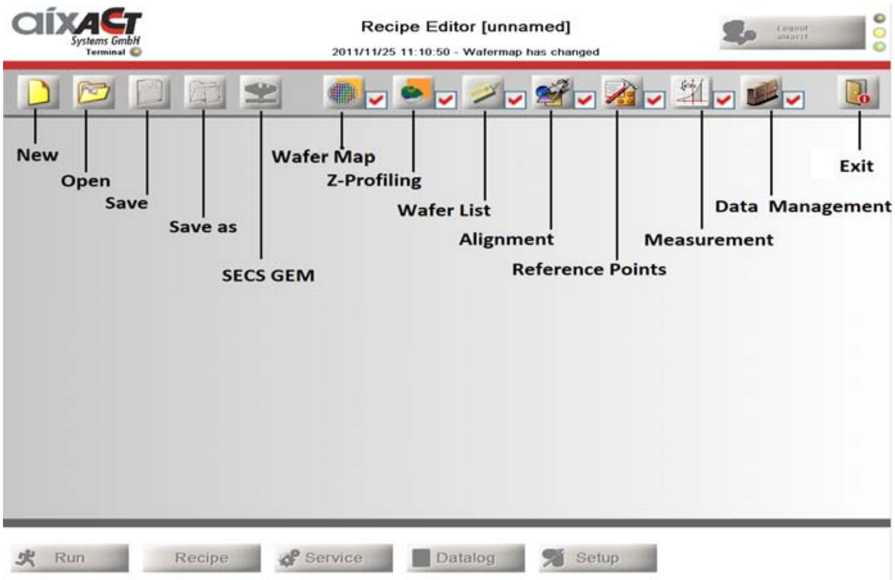
One of the benefits of the aixDBLI tool is the homogeneity proof of the piezoelectric properties. The main result of the tests performed with this tool is the wafer map information, which allows at a single glance to judge the wafer distribution of a certain parameter. These tests require certain flexibility in wafer layout and tests to be performed. Both have been taken into account when realising the software interface presented hereafter.
In addition to these plans we have integrated additional functionality as poling and treatment procedure, which are very helpful in forming the film properties after deposition and in preparing reliability studies on the film, after top electrode has been deposited and patterned.

## 2.1 Recipe Editor

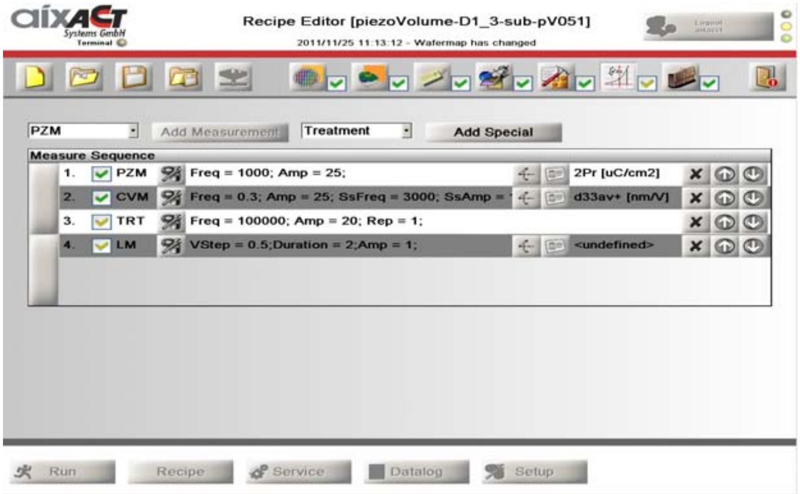
The recipe editor offers all necessary settings in order to create a recipe for a certain test procedure. The software guides the user through these steps to ensure it is completed correctly by the end user. This level of software is reserved for a super user not for the regular operator.
The seven steps are

1. Wafer map
2. Z profiling
3. wafer list
4. Alignment
5. Reference Points
6. Measurement
7. Data management

Beside the standard tests described before, displacement measurement and piezoelectric coefficient and leakage current measurement additional functionality we have implemented a so called treatment function, which allows to generate a pure electrical signal which allows to perform reliability tests with the tool, even though the tool is not designed to perform reliability tests on a single dot, because it would be too expensive testing.



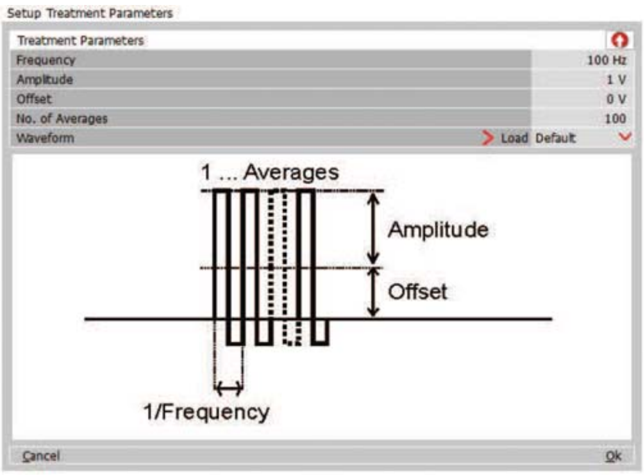

Recipe editor dialog




Measurement sequence with treatment function

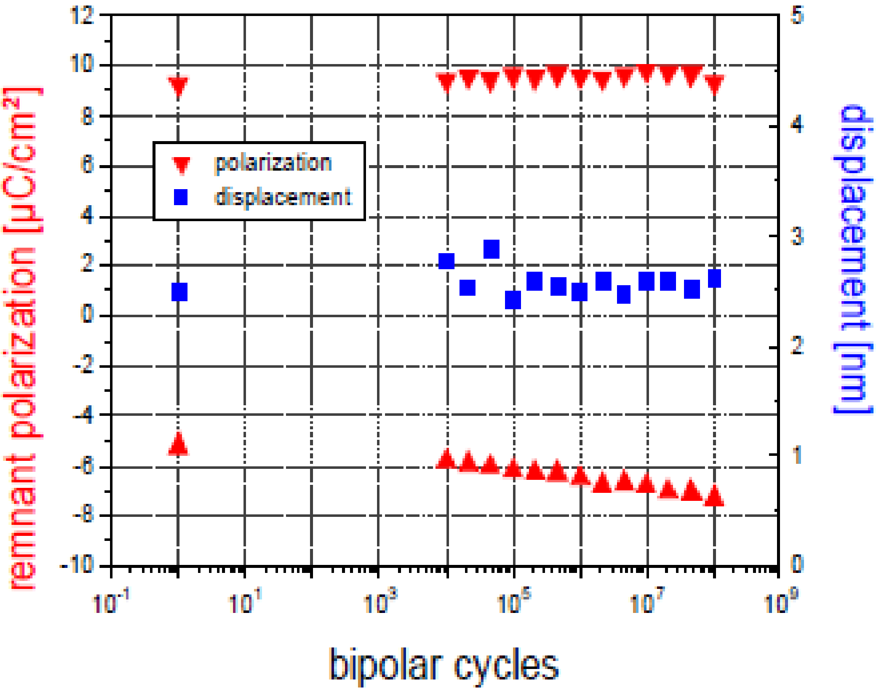
The figure shows the different measurements that can be performed with the aixDBLI system in a sequence. Beside displacement, d33,f and leakage current measurement the treatment occurs as a measurement type even though it does not output data.

## 2.2 Reliability testing



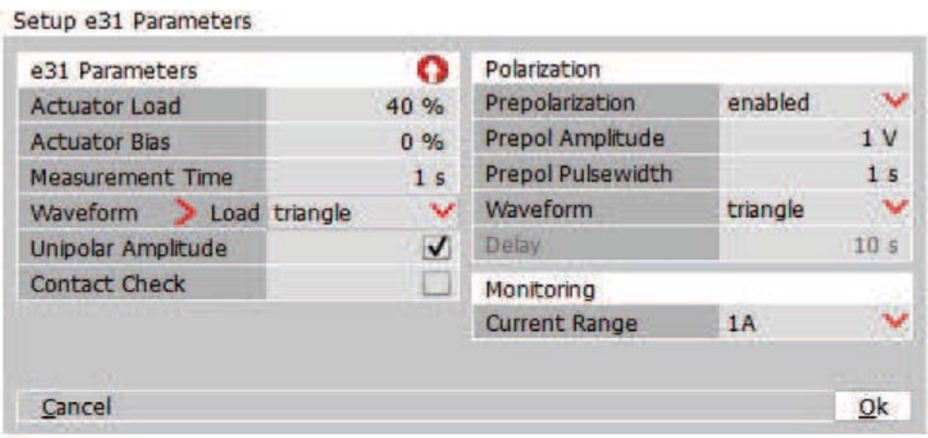

Advanced TRT (treatment procedure) parameter with excitation signal

The adjustable parameters for treatment are the waveform of the signal in use, the frequency and amplitude and offset of the signal and the number of pulses that should be generated. It is pretty much similar to the fatigue signal, but it allows pure DC treatment to investigate imprint and creep. In the same way, retention can be investigated. This is a really powerful feature for reliability testing



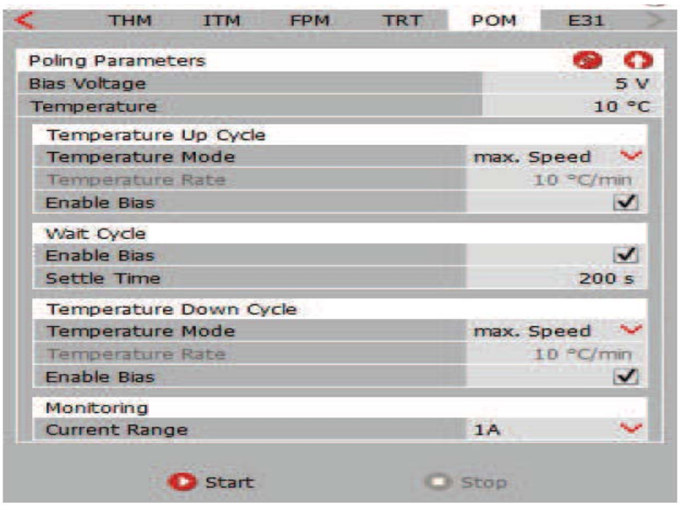

Fatigue data recorded utilizing treatment procedure

For a more convenient use the e31,f user interface has been improved in order to derive this important coefficient right in the measurement dialog.

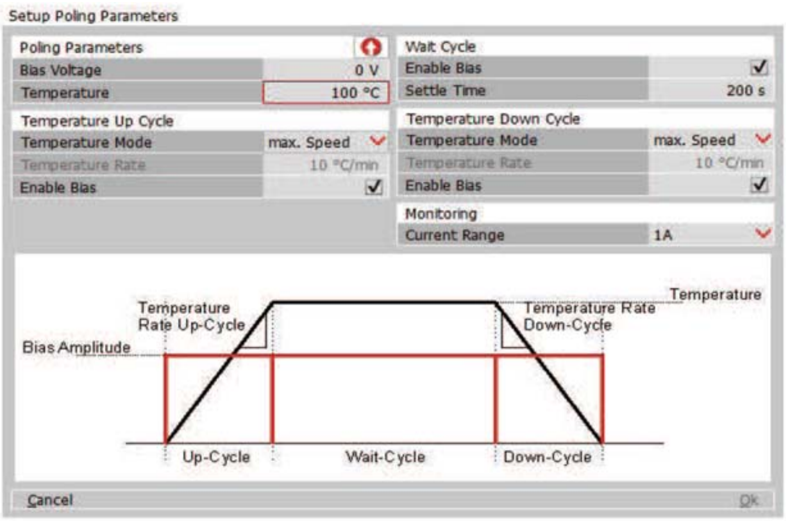



Advanced e31,f measurement dialog

## 2.3 Poling procedure




During the project the poling procedure has been identified as very important in view of the forming of the material in order to achieve very high piezoelectric coefficients. All the results that were derived during the project in view of different poling conditions were taken into account and realized within this software. Values up to e31,f of almost 20 C/m2 were achieved after poling. This is world record in published e31,f values.



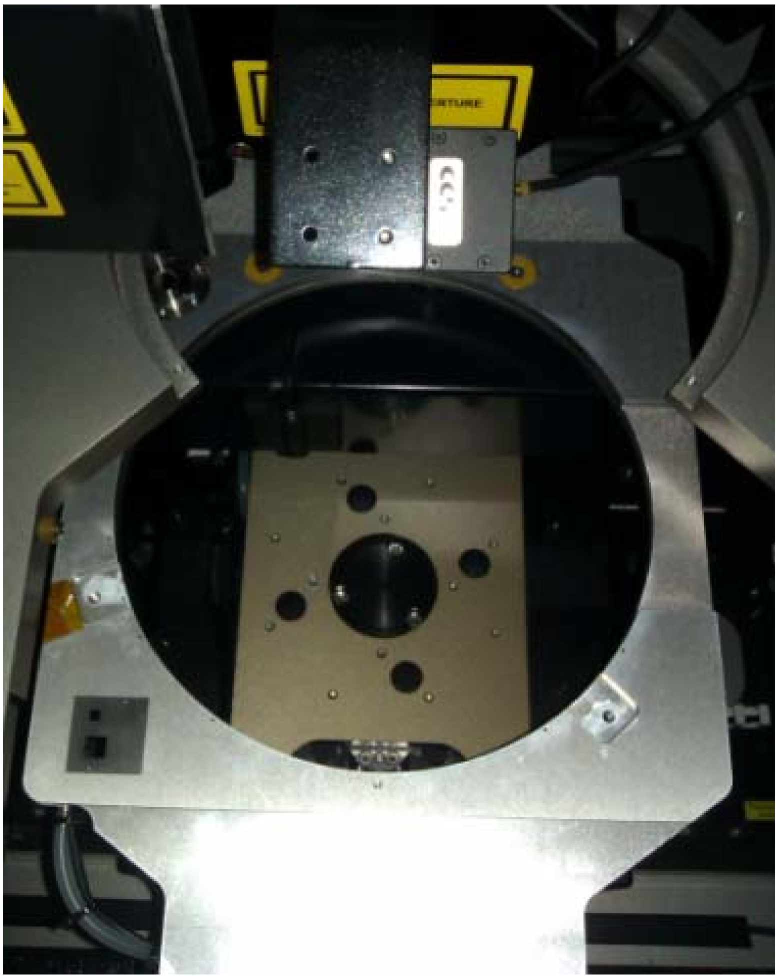

Advanced Poling Measurement dialog with parameter and excitation signal

# 3 VARIABLE WAFER SIZE, DEVICE TESTING, BLOCKING FORCE MEASUREMENT – ALL WITHIN A SINGLE TOOL – THAT IS UNIQUE

## 3.1 Flexible wafer size

The maximum wafer size that can be handled by the tool is eight inch limited by the chuck system of the auto prober. From our market understanding there is currently no need and will be no need within the next three to five years for 12 inch, because etching and deposition tools do not offer this size.

Smaller wafer sizes can be handled. Even small wafer pieces like 1 inch by 1 inch or 1 cm by 1 cm can be mounted and measured. The change from one wafer size to the other can be managed in a couple of minutes very easy.

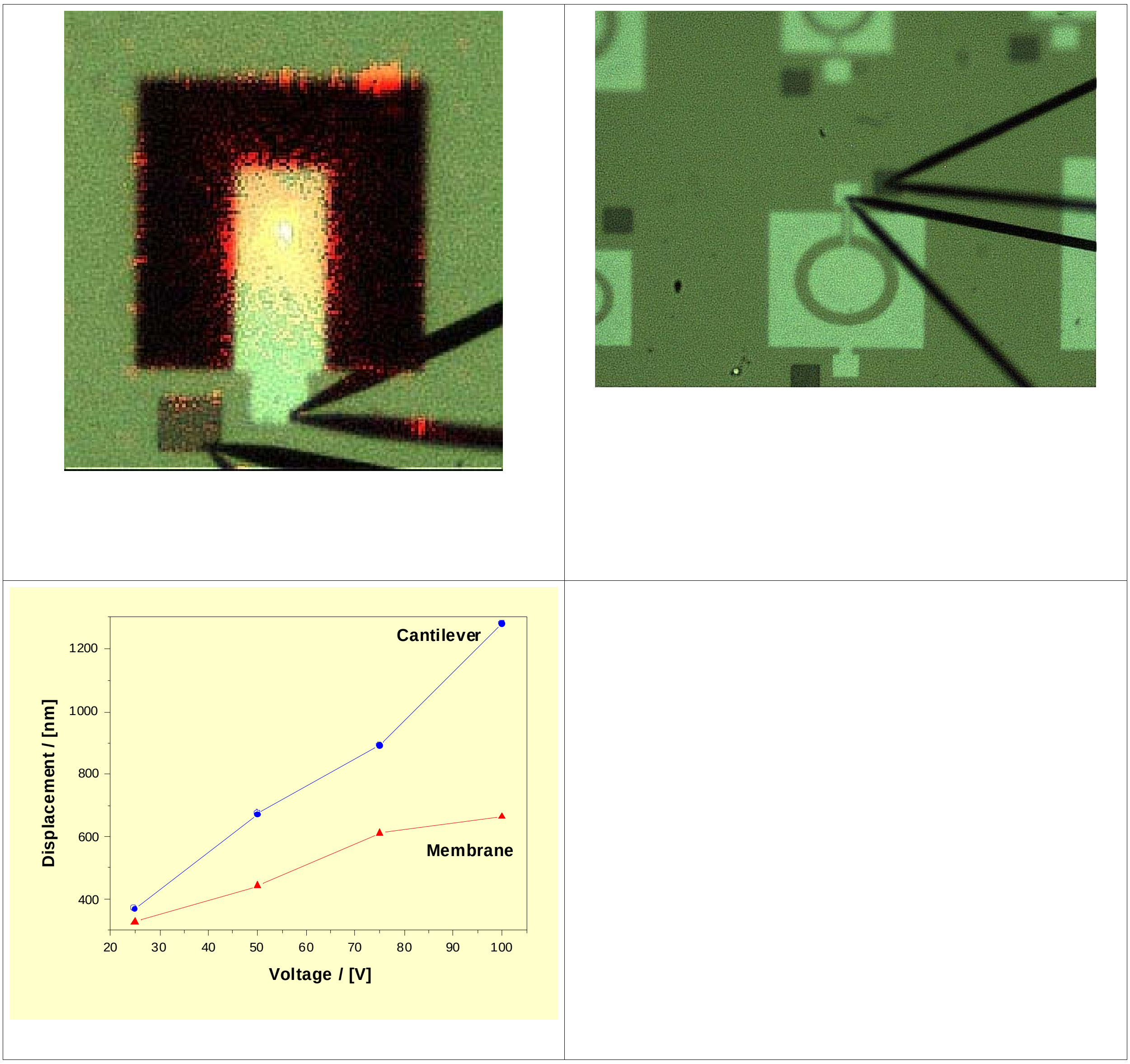


Wafer chuck of the aixDBLI tool with permanently mounted reference x-cut quartz. By mounting an insertion ring the system can be adapted to any wafer size

View inside the aixDBLI chamber, showing the chuck system and DBLI optics the single beam option and the force measurement unit.

## 3.2 Device testing utilizing single beam functionality

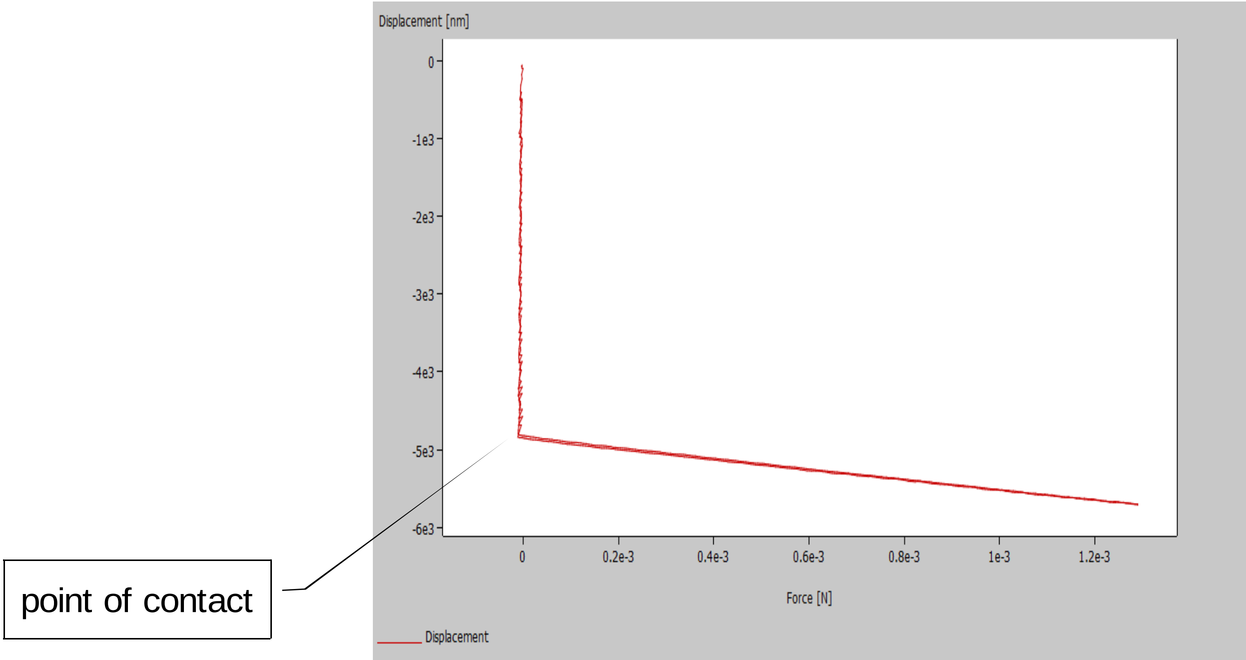
The functionality of the tool has been further extended by single beam laser functionality. This has been a request from the market, that one and the same tool can test the deposited film as well as the manufactured device. As shown below, membrane and cantilevers have been tested with a displacement of a few micrometres in comparison to the deflection of the deposited film of around 1 nm.




Cantilever and membrane structure to be tested by single beam functionality of aixDBLI system

## 3.3 Force measurement

There are applications that require further knowledge which exceeds the data of displacement, piezoelectric coefficient and membrane deflection. Actuator applications request for mechanical data like blocking force, RF switched specifically need essential data like on-resistance of the switch as a function of the applied force. Both measurements can be performed with the aixDBLI tool on wafer level.




Blocking force measurement on a silicon reference sample utilizing the aixDBLI system 1.3mN force with 1um displacement

# 4 SUMMARY

The aixDBLI tool fulfils in any extend the defined goals of the project. It exceeds in terms of long term stability, resolution on eight inch wafer and flexibility (standard test, reliability test, poling procedure and measurement of devices and blocking force measurement the expectations that AIX had.

The whole industry related to piezoelectric MEMS is interested in the aixDBLI tool. The test systems meet the requirements and demands of the market. It is expected that with start of mass production of piezoMEMS this tool will be first choice of industry.